Astroparticle Physics Planning in Europe

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After 2012-2013 Astroparticle Physics in focus
Going up and down the cosmic ladder

« Another » Jacob's ladder?

The Astroparticle domain after LHC/PLANCK/ν results can be reduced to 2 fundamental questions:

1) Are there any intermediate scales between the EW scale and Inflation ? If yes how many and where are they ?
   - Inflation, dark energy and matter
   - Neutrino properties and proton decay

2) Are there new energy scales at work in the most violent phenomena of the Universe? How do particles and fields shape the formation and evolution of cosmic structures ?
   - High energy photons, neutrinos, CR
   - Gravitational waves

A short history of European Astroparticle Physics Coordination APPEC (2001-2013)

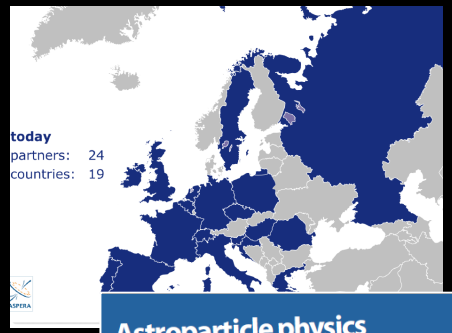
✓**2001-2012** **A**stroparticle European Coordination (APPEC). Started with 5 agencies

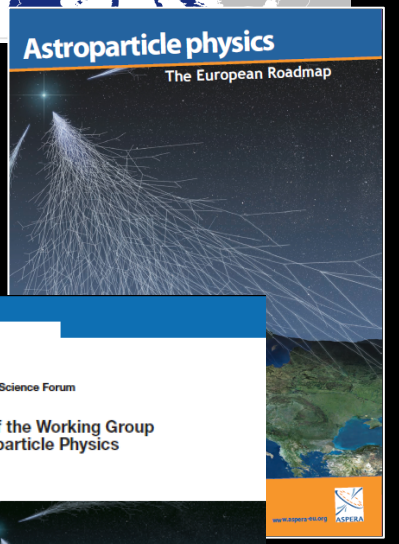
✓**2006-2012** ERANET ASPERA (EU funds FP6 and FP7)

- ✓ 19 countries totalling a program of 3000 researchers and 220 M€/year consolidated funds.
- ✓ Roadmap (from definition 2008 to priorities 2011)
- ✓ Accompanying actions (next slide)
- ✓ Initiative for global coordination:
  - ✓Workshops (Brussels, Paris),
  - ✓OECD/GSF group APIF

2012 Astroparticle European Consortium (APPEC)

- ✓ Agency funded coordination (MoU).
- ✓ Currently 15 European countries
- ✓ 3 functional centres (France, Germany, Italy) + Spain





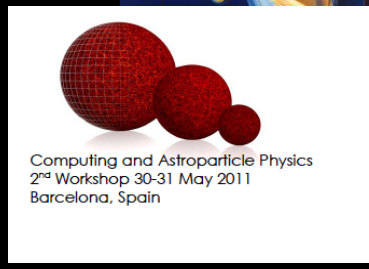
APPEC (ASPERA) actions

Reports and presentations in www.appec.org

- R&D (common funding, total 9 M€; 2010-2012)
  - Dark matter (DARWIN, EURECA) , CTA, Neutrino mass (GERDA, LUCFIFER) , Auger, Low energy neutrino (LENA, ORCA,PINGU) and ET (GW)

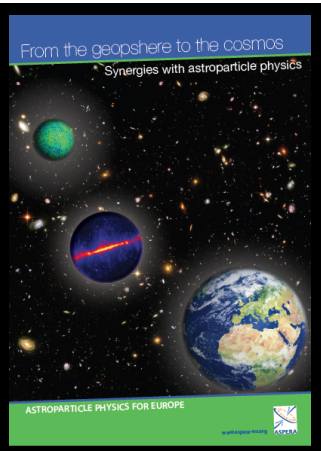
- Industrial contacts (Munich, Pisa, Darmstadt; 2010-2012)
  - Photosensors, Electronics, Mirrors, Lasers, Cryogenics, Vacuum

- Computing (Lyon, Barcelona, Hannover; 2010-2012)
  - Astroparticle computing ranges from signal analysis (GW) through event crunching (CR) to large surveys (DE).
  - Towards a white paper (2014). Discussions with CERN and others for a "new" computing model.



- Interdisciplinarity (Paris, Amsterdam, Durham; 2010-2012)
  - Geosciences, Biodiversity, Climate,…

- Theory (Particle Astrophysics, Cosmology Program, PACT, 2013)
  - ✓ Workshops, School, common funding of postdocs



European programmatic context

- APPEC: a new SAC (First meeting October 2013) mandate to produce a roadmap update "within constraints of agency budgets" by spring 2014.
- CERN: European Strategy for Particle Physics (APPEC input)
- ESFRI: (European Strategic Forum for Research Infrastructures) provides input to Ministries (new chair J. Womersley). An advisory group to ESFRI judging projects on financial and managerial maturity ranked:
- CTA rank B ("might be able to achieve maturity by 2015, if substantial actions are implemented to address the bottlenecks and weaknesses") and
- KM3NET rank C ("minimal chances of achieving maturity by 2015 for various reasons").
- The ESFRI group currently re-examines the projects, adding scientific criteria to the evaluation (2014). ESFRI opinions are a determinant input to EU funding (central infrastructures, data access, legal entities etc). Update of the roadmap in 2015/2016
- European Union 1-1-2014 start of the Horizon 2020 (H2020) program (70 BE in 7 years). APPEC actively coordinates in view of H2020 calls of funds on:
  - Large Research Infrastructures (CTA, KM3NET, see above)
  - Networking (Gravitational waves, Underground labs)
  - Design studies, R&D, individual grants, postdocs, e-infrastructures, KT,
  - International coordination on RI .
  - BUT CONSTRUCTION FUNDS HAVE TO COME DIRECTLY FROM THE AGENCIES

Summary of the roadmap statements of November 2011, specified in January 2013 as input to the European Strategy of Particle Physics

APPEC supports:

I. In the category of medium scale projects: the timely completion of the 2nd generation upgrades of gravitational wave antennas, as well as the upgrades/constructions towards ton-scale detectors for dark matter and double-beta neutrino mass experiments.

II. In the category of large-scale projects a high priority is given to the construction of the Cherenkov Telescope Array (CTA), and strong support for the first phase of KM3NeT, as well as R&D towards the definition of the next generation ground-based observatory for high energy cosmic rays.

III. Finally there needs to be coordination with other European/non-European organizations for the realization of billion-euro scale projects at the 2020 horizon, in particular a 50-500 kt scale low-energy neutrino astrophysics/ proton-decay detector. Other projects on this cost scale are_dark energy surveys on ground and in space, and in a longer perspective gravitational wave antennas with cosmological sensitivity on ground and in space.

The European Astroparticle Physics Roadmap I
Timely entry in full operation of projects in construction
(➔ 2015-2016)

Gravitational waves

- advVirgo, advLigo . Commissioning start in 2015
- In space (ESA) LisaPAthfinder (integration started) launch 2015

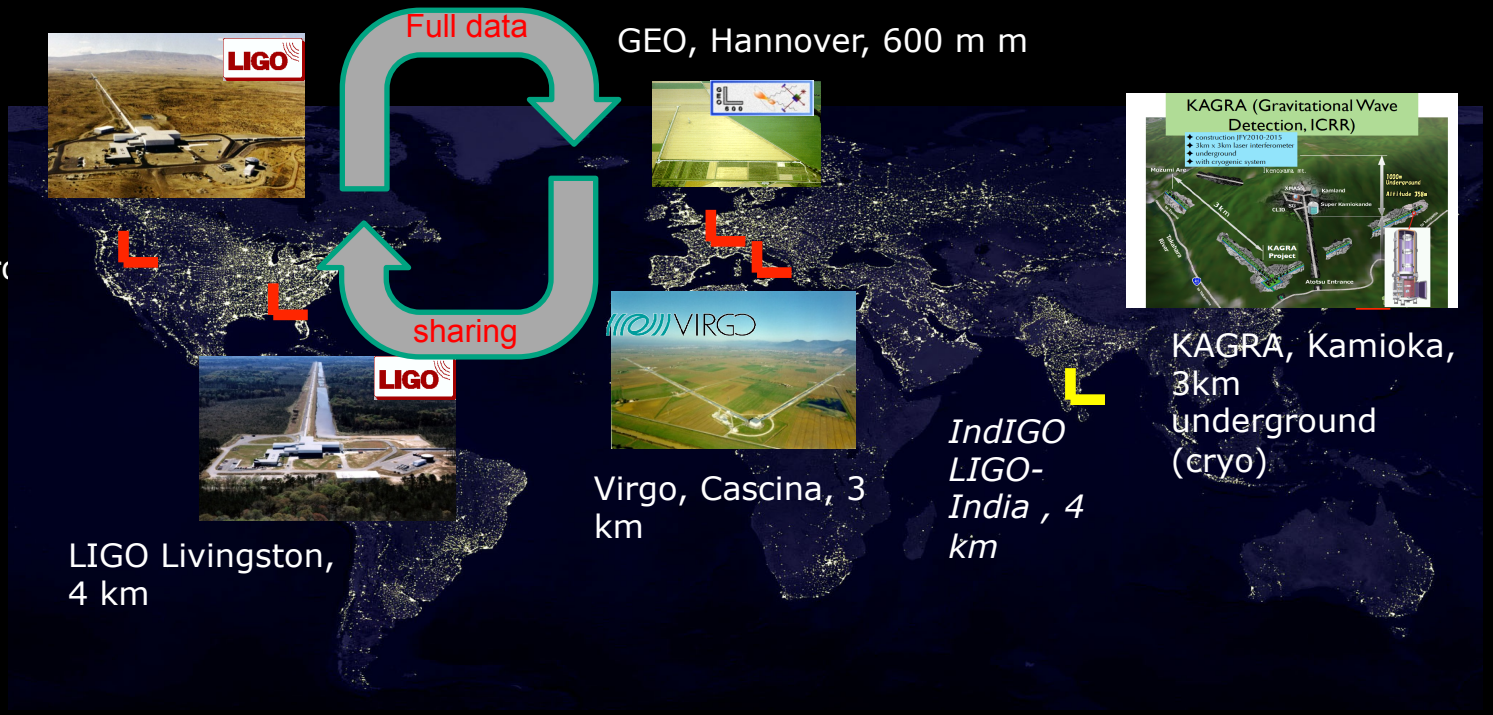
Underground science

- Dark matter towards σ - 10^{-12} pb^{-1} sensitivity
- Xenon 1t (data-taking by 2015) EDELWEISS III final results by 2015, DarkSide (started end 2013), ArDM start running by 2014
  - *R&D and Conceptual Studies: EURECA, a multiton experiment DARWIN*
  - *R&D and Conceptual Studies: Directional DM, Axions (IAXO, ALP)*
- Neutrino mass towards 30-50 meV in double beta effective mass
- Single β ➔ KATRIN data-taking 2016 (200 meV)
- Double β ➔ GERDA-II, NEXT, SuperNEMO prototype (commissioning 2014), Cuore (full detector data-taking 2015)
- *R&D: E.g. LUCIFER(Se, GSasso),LUMINEU(MO, Modane)*
- Neutrino oscillation prototype for a large detector
- Support for a LAr prototype tests at CERN North Area

APPEC also supports networking funds (ca 7 ME) for Gravitational waves and underground science in the context of Horizon 2020

Gravitational wave antennas

A paradigmatic worldwide collaboration



✓ApPEC priority: the timely completion of the 2nd generation upgrades of gravitational wave antennas (2015).

✓MoU VIRGO-LIGO-KAGRA

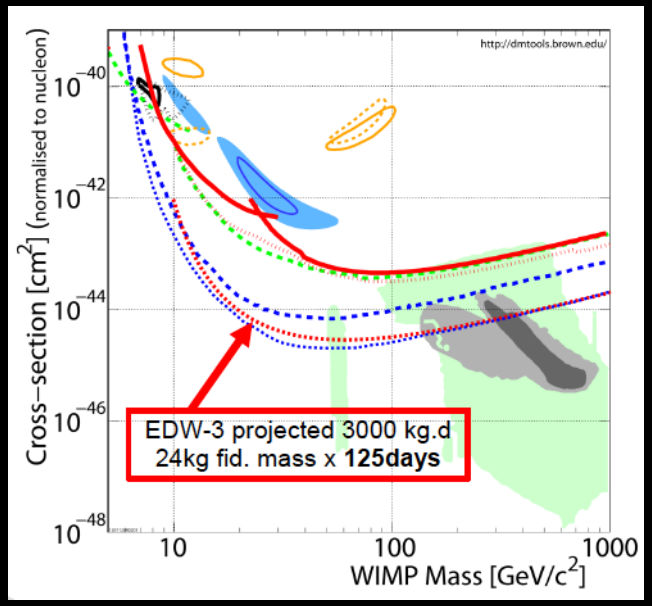
✓Towards a first detection in 2016-2018

Direct dark matter detection I

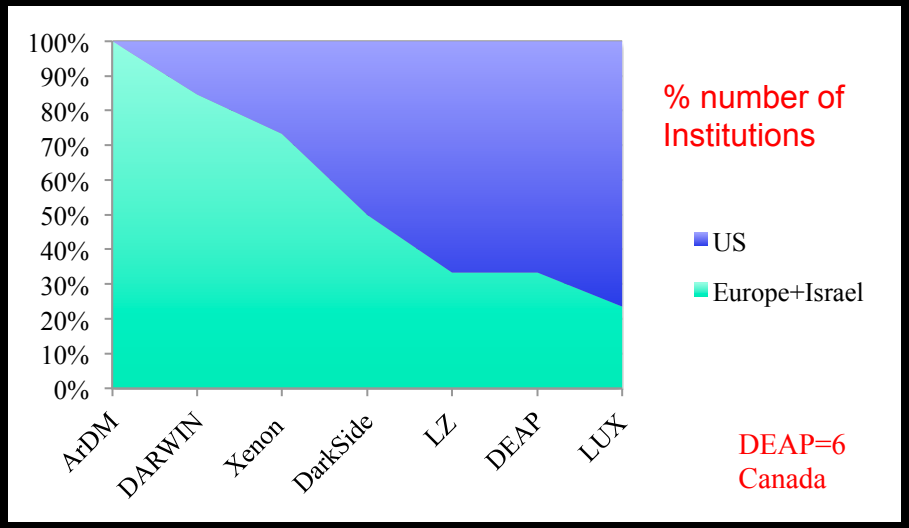
A paradigmatic worldwide dispersion

APPEC Roadmap: WIMPs will be put in a severe, if not conclusive, test during the next 10 years. (LHC, direct and indirect detection). In case of discovery both accelerator and non-accelerator experiments will be needed to determine the physical properties of WIMPS.

Direct Dark Matter direct detection II



Large US-EU correlation in DM experiments,
eg in Noble liquids (data L. Baudis)
LZ+DARWIN+DarKSide= 100 Inst. US-EU 50%-50%

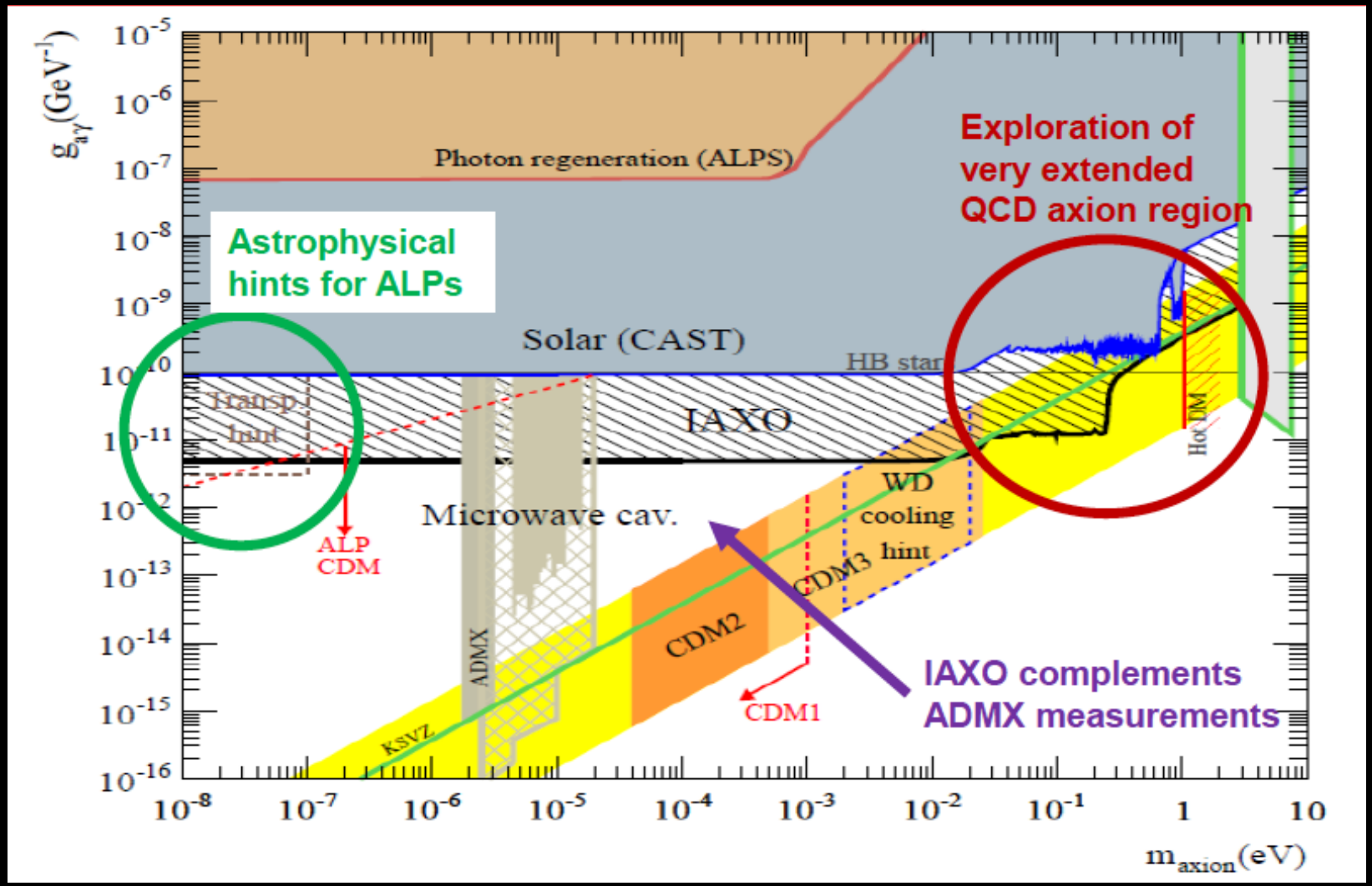


- ✓ XENON 1t start data taking by 2015
- ✓ EDELWEISS III (24 Kg) sensitivity close to LUX by spring 2014, x4 by 2015
- ✓ DarkSide, ArDM (30-100 Kg) data-taking in 2014

1. *Towards a 50 M€ multi-ton experiment (LZ,DARWIN, DarkSide). Possibilities of coordination in G3 ? Care wih low energy region, ν physics…*
2. *European Bolometers(CRESST, EDELWEISS) in EURECA discussions of close cooperation with CDMS*
3. *Directional R&D*

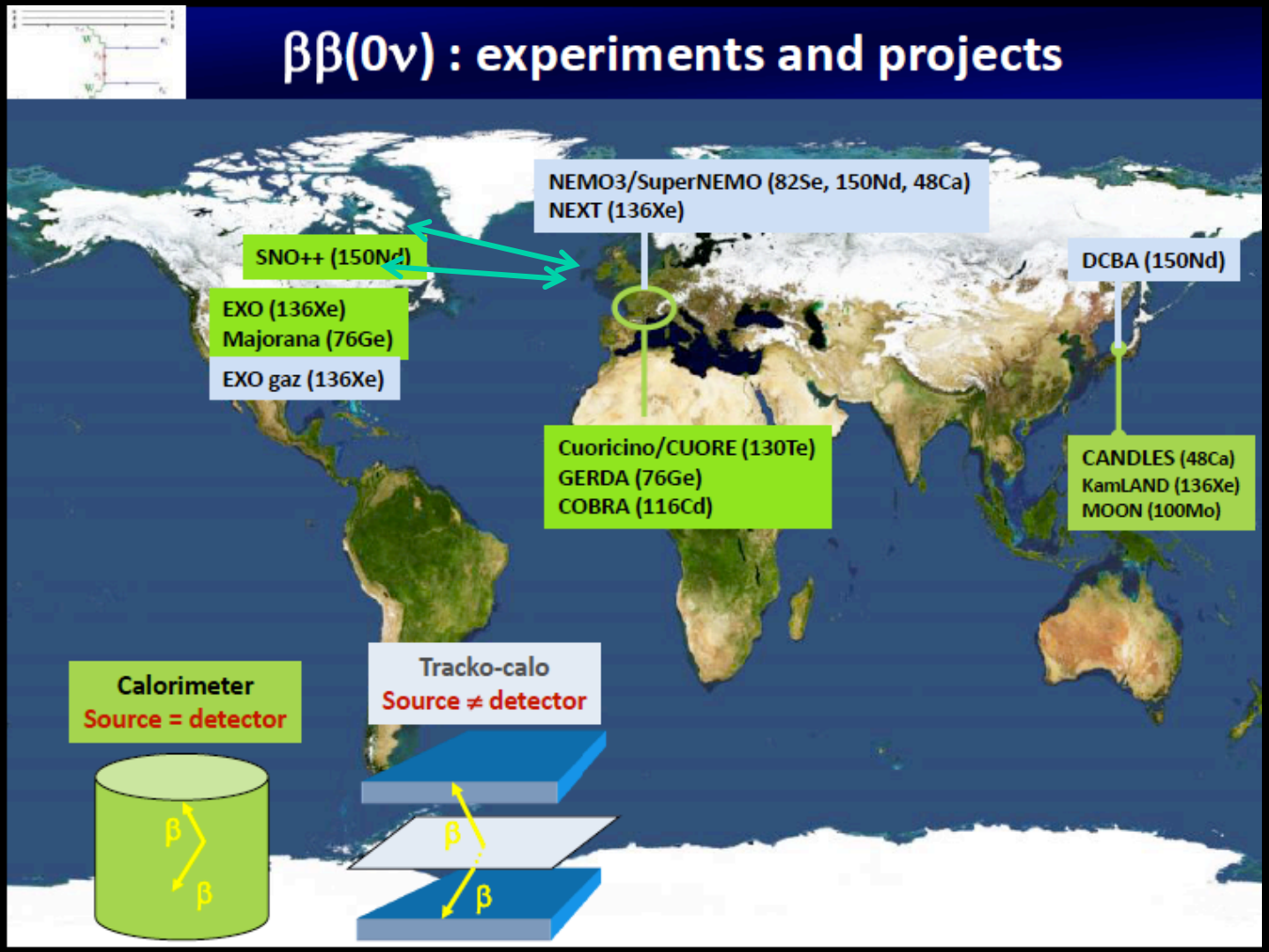
Axions

Helioscopes (CAST/IAXO) and Lasers in Europe (ALPS)



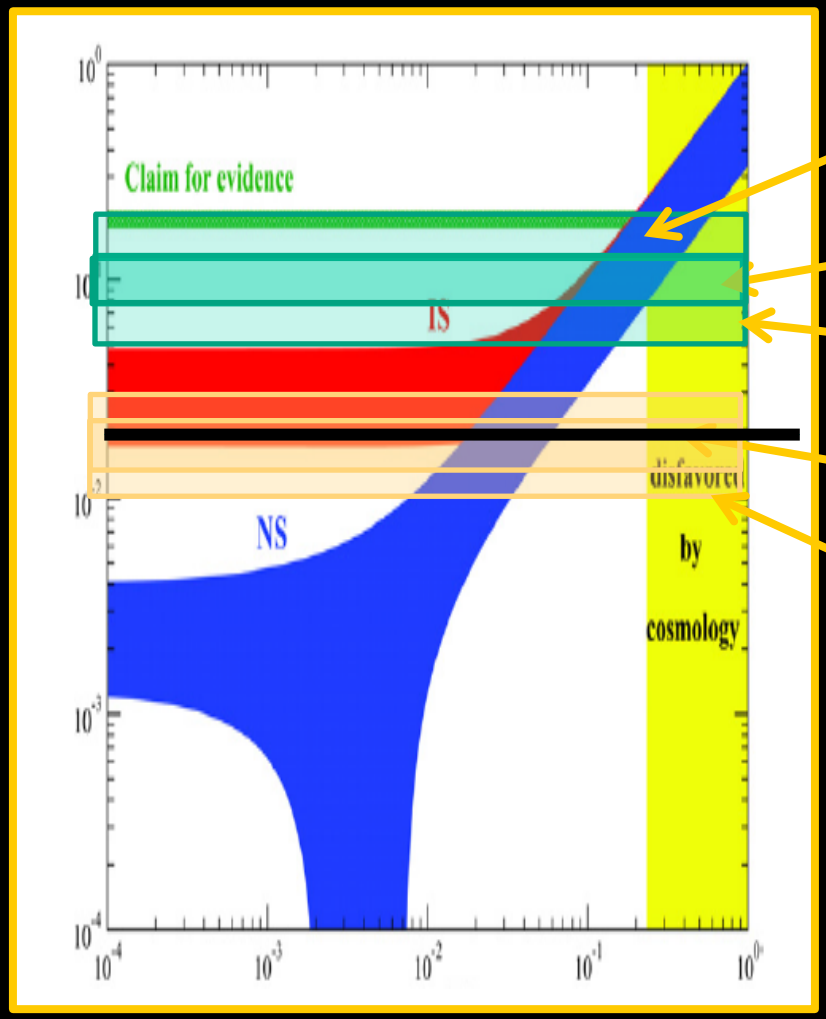
Neutrino mass and nature I

Testing the Majorana nature of neutrinos through the detection neutrinoless double beta decays. Its theoretical importance cannot be overstated.



Neutrino mass and nature II

0νββ approaching/exploring the inverted hierarchy



Ultimate EXO-200 (80-200 meV)
(4 y + Rn removal)

GERDA phase-2 (75 - 129 meV)

CUORE (51 – 133 meV,5y)

20 mEV
0.5-5 evts/y/ton

NEXT, SuperNEMO (100Kg,5y)

Scintillating bolometers
(350 kg, 5 y) (13 – 36 meV)

Initial nEXO (EXO-200-like 5 tons,
10 y) (10 – 30 meV)

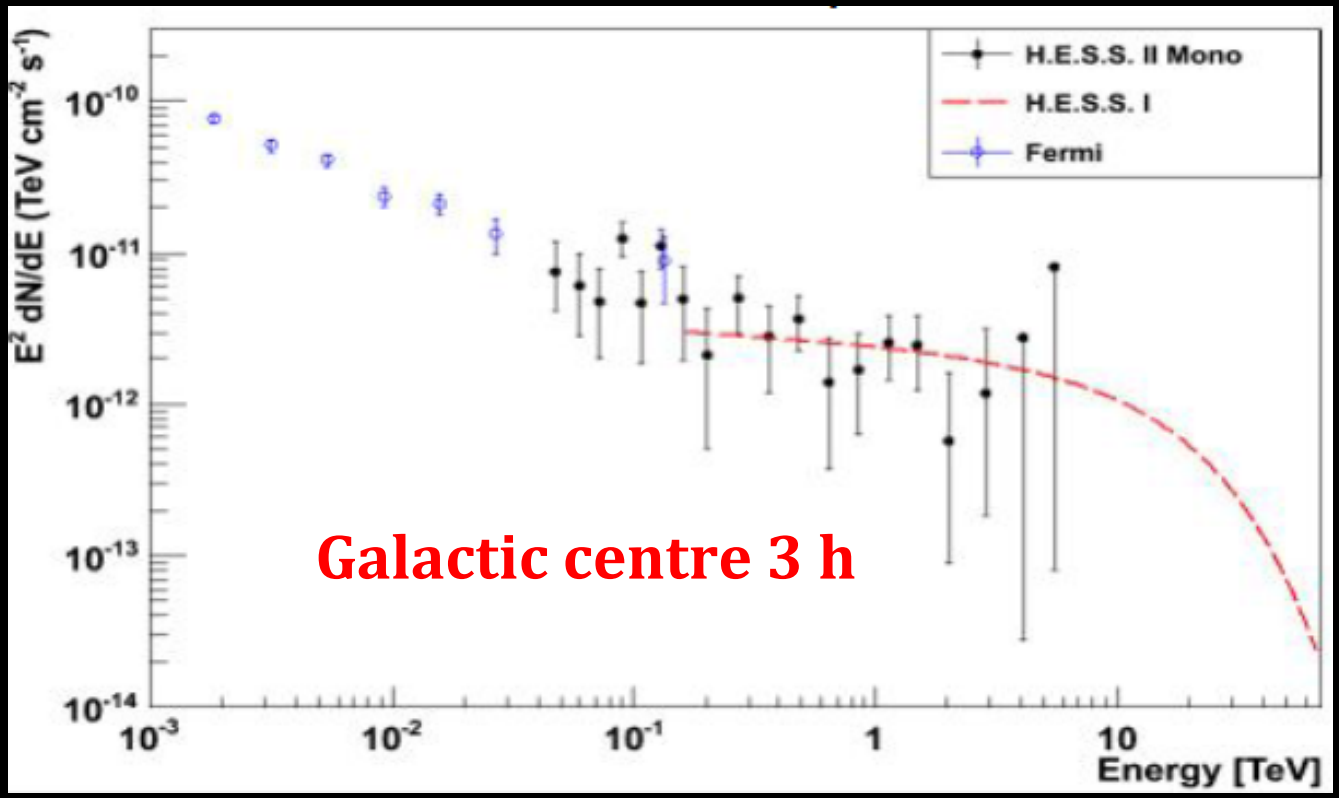
MOU between GERDA and Majorana for
a ton-scale experiment

The European Astroparticle Physics Roadmap II
The High energy cosmic ray program
(2015-2020)

- High Energy photons
  - CTA, high priority of the APPEC roadmap, CDR by 2015
- High energy neutrinos
  - KM3Net, APPEC support for phase 1
  - *ICECUBE support by a large European community*
- Ultra High Energy cosmic rays
  - Auger, small to medium scale upgrade proposal to be evaluated end of 2014, start of deployment in 2015
  - *EUSO, support by a large European Community*

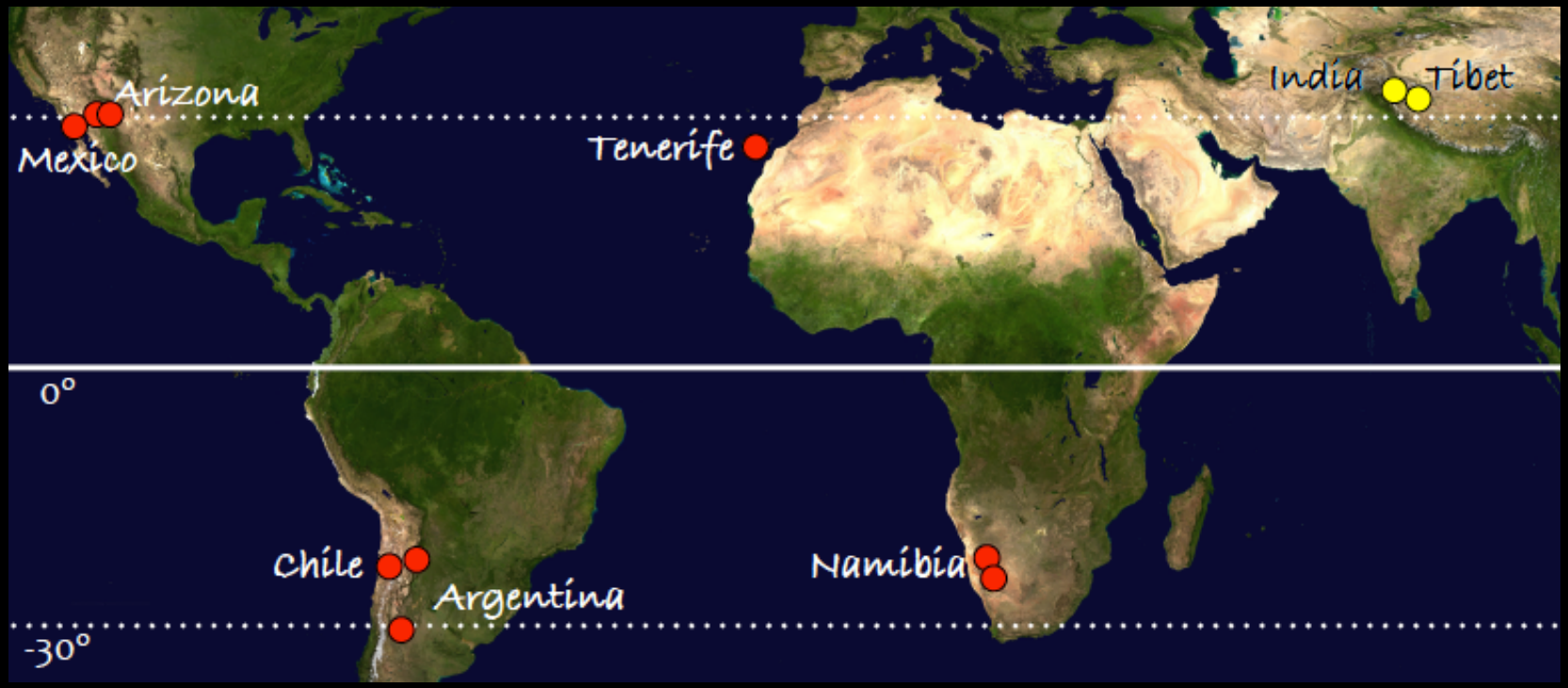
High energy photons I
European Legacy

- **Ground: HESS and MAGIC, participation to VERITAS**
- **Space : Strong participation to FERMI**
- **HESS2 exploitation to 2018. Threshold < 40 GeV overlap with FERMI. MORE Results Soon.**



High energy photons II
CTA

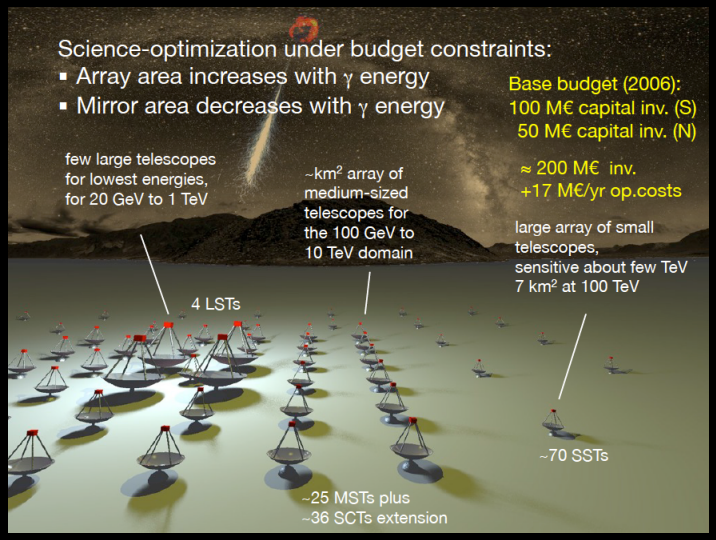
APPEC ➔ In the domain of TeV gamma-ray astrophysics the **Cherenkov Telescope Array** (**CTA)** is a worldwide priority project.



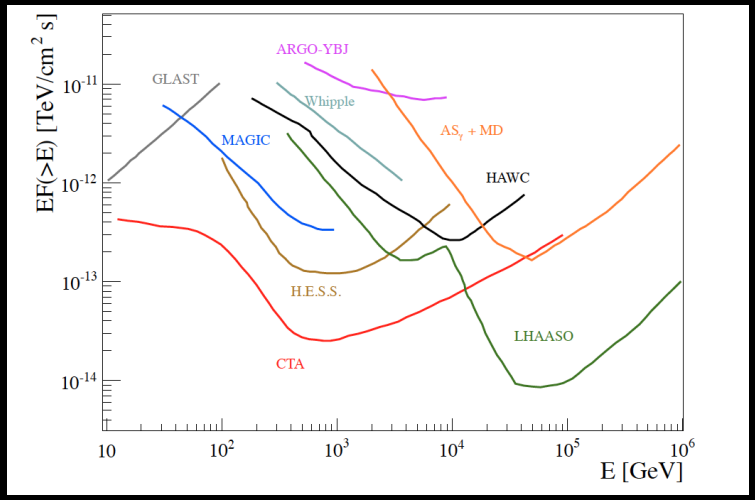
- March 2014 Site Selection Committee ➔ recommendations for South and North
- End of 2014 Resource Board decisions on sites

High energy photons III
CTA

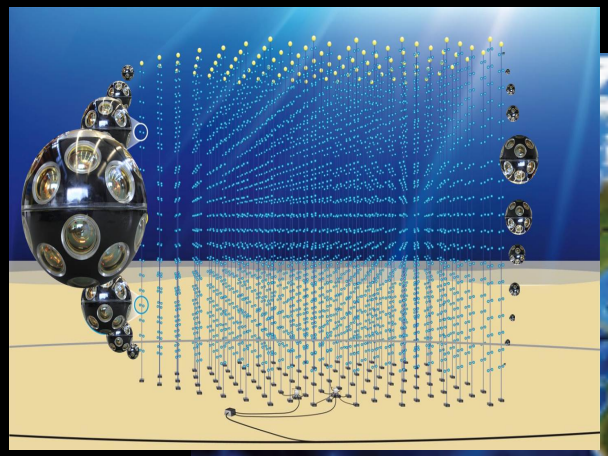
- Managerial structure in place
  - RRB, AFAC, STAC (chair R. Blandford)
- Technology prototypes on track
- CDR submission end of 2014
- 2015, Production Readiness Review and decision to start (?)
- Construction 2016-2020
- Start of observations by 2017



- Well seen in ESFRI roadmap. In good position to obtain EU funds (5-10 M€) from Horizon 2020 for the preparatory phase and setting up of the central infrastructure
-
- Issue: what legal entity for an international Infrastructure? Intermediary Legal Entity: German GmbH



High Energy Neutrinos I

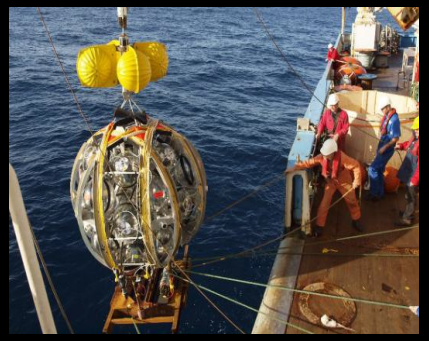


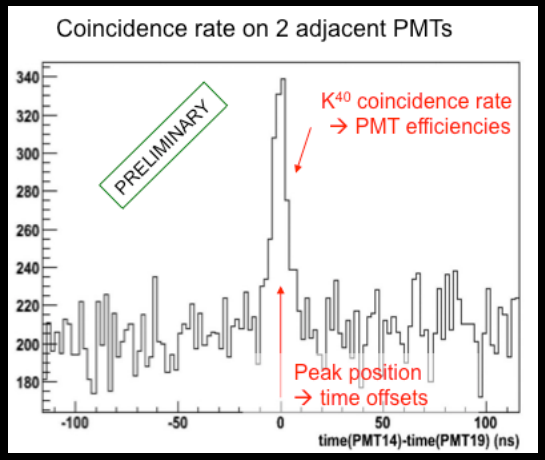
Nothern Hemisphere projects and IceCube have signed (October 2015) an MoU for a Global Neutrino Network (GNN).

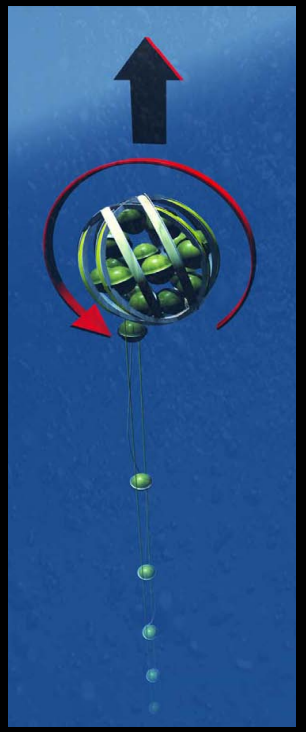
High Energy Neutrino II

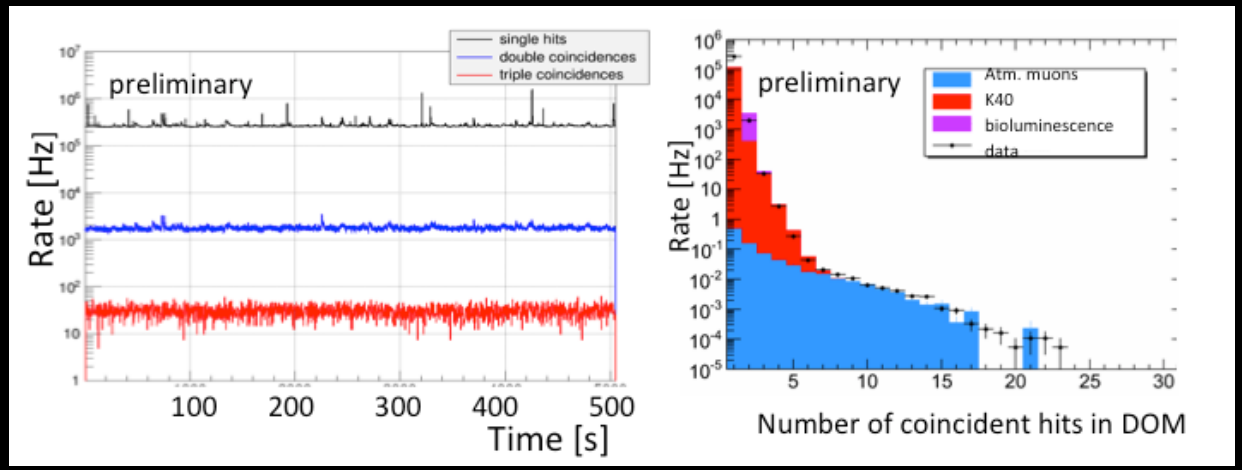
KM3Net technical progress

- Multiple successful deployments of the string
- Successful operation of of the 31 PM DOM
- String cost ¼ of Antares







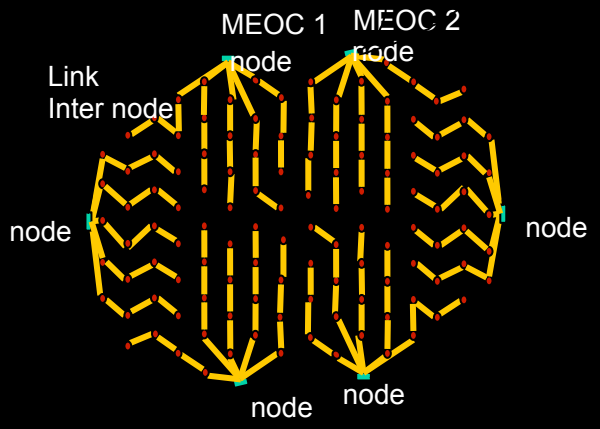


High Energy Neutrino III

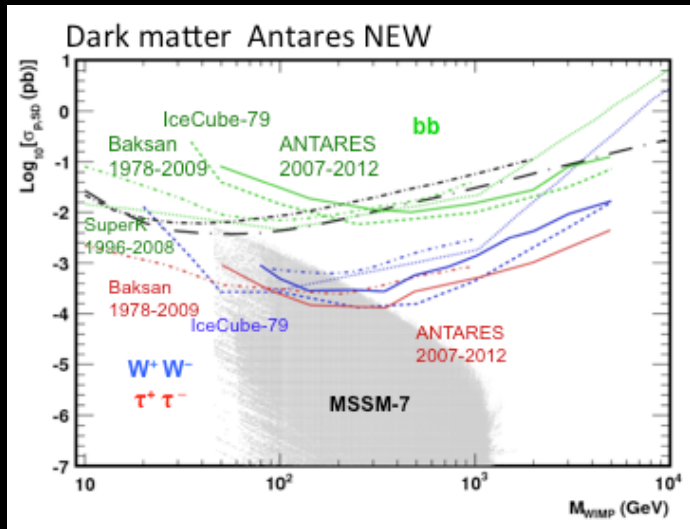
KM3Net, Project progress

- Management structure set up (Feb 2013)
- Phase-1 (funded, 31 strings, 33 ME, majority structural funds)
  - Deployment in 2 sites (Capo-Passero/Toulon)
  - Start installation in Italy Autumn 2014
  - Start installation in France Spring 2015
  - Phase-1 Complete mid-2017
- Phase-1.5 150 -200 strings to check ICECUBE (demand of extra 50-60 M€)
- Phase-2 700 strings x5 ICECUBE
- Feasibility studies of a smaller array ORCA to measure the mass hierarchy (ORCA-PINGU)
- Passage from ESFRI 3 December 2013 (today)
  - Support letter from external STAC (chair M.Spiro)

ApPEC: support for the first phase of KM3NeT.



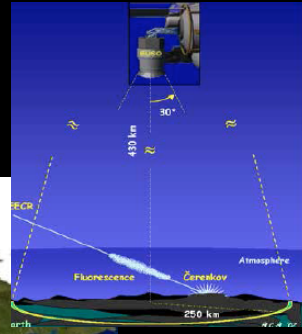
Current optimisation: Blocks of 115 strings, 90m apart, 18 DOM/String, spacing between DOM's 36 m



High energy cosmic ray observatories I

AMS

…

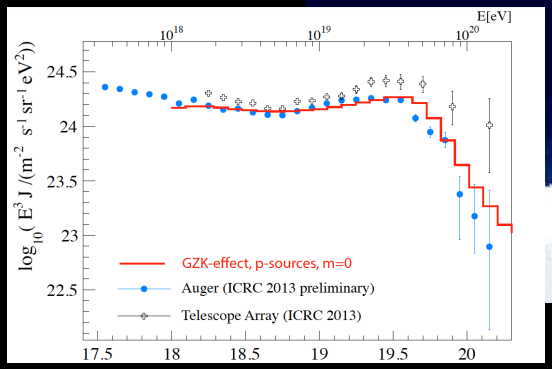


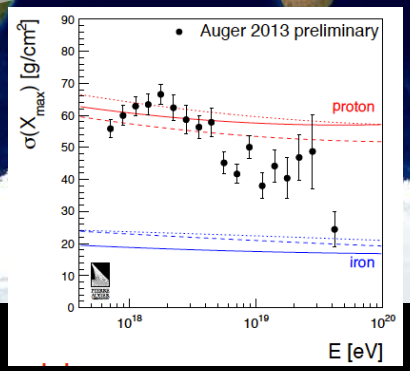
JEM-EUSO

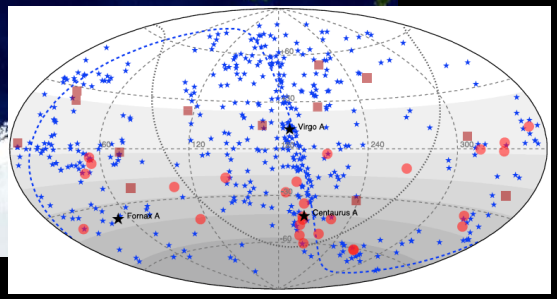
Telescope Array

LHAASO

Auger

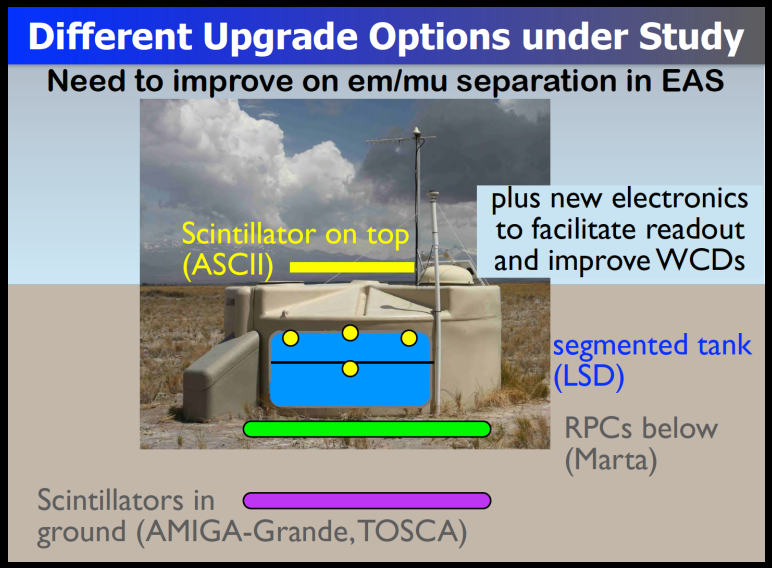


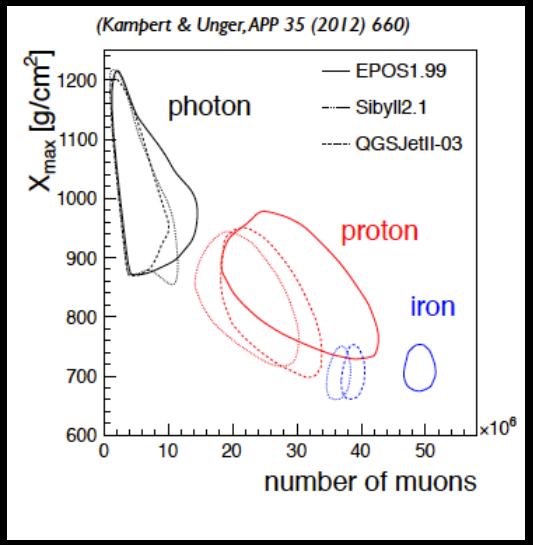




- Spectrum: GZK cutoff or end of the energy reach of the accelerators?
- Composition: fraction of protons? Anisotropy ? GZK photons or neutrinos?
- Go to 200 evts > 60 EeV/y (JEM-EUSO) ?

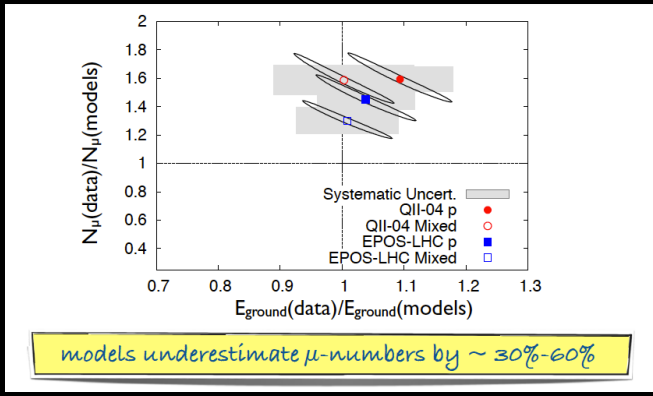
High energy cosmic ray observatories II
Auger upgrade



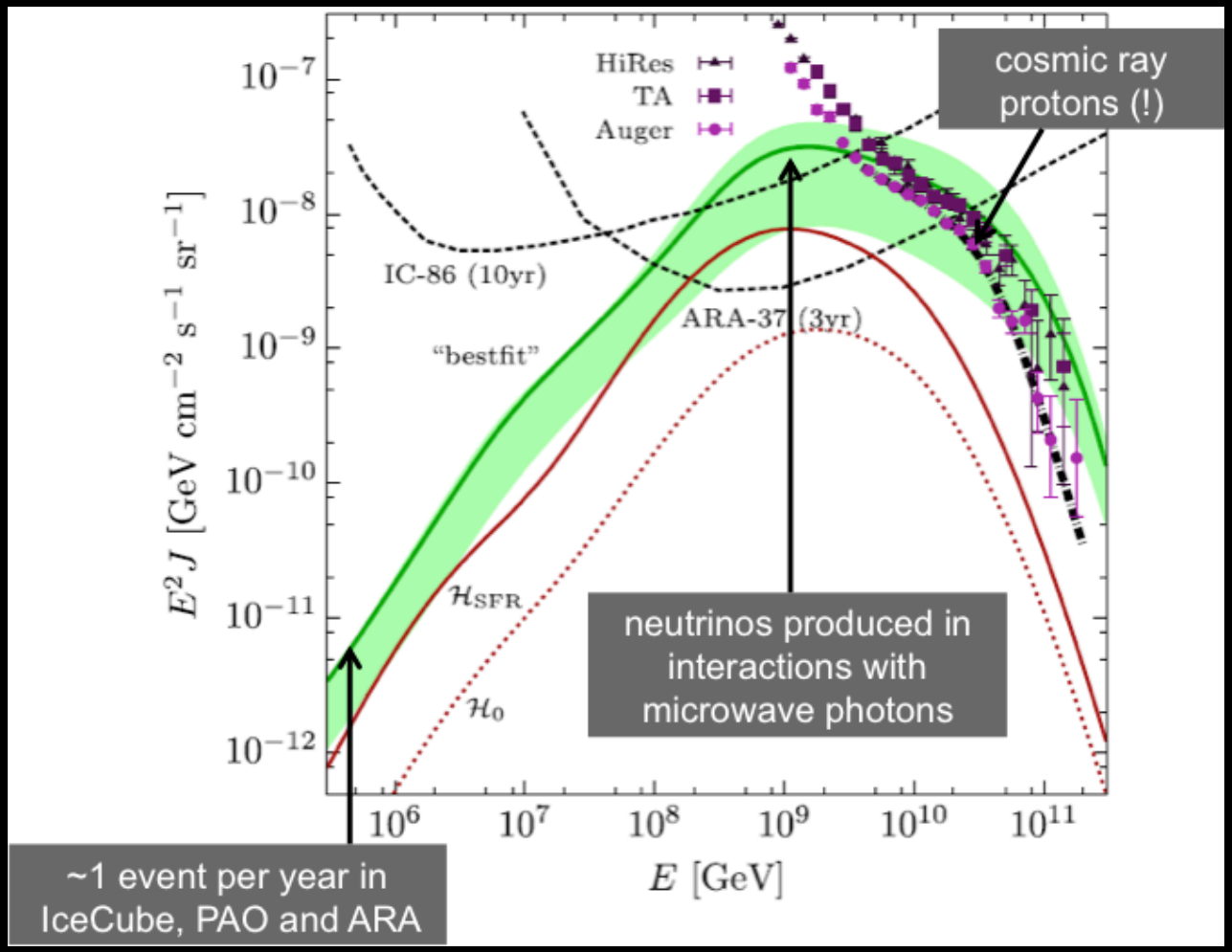


Auger collaboration prepares a small to medium upgrade proposal to be evaluated by STAC (ch. F. Halzen) and discussed by agencies by the end of 2014

In parallel one needs to understand the MC-data differences. A collaboration with LHC teams is an urgent matter.



High Energy mutimessenger sensitivities start to be comparable (courtesy F. Halzen)



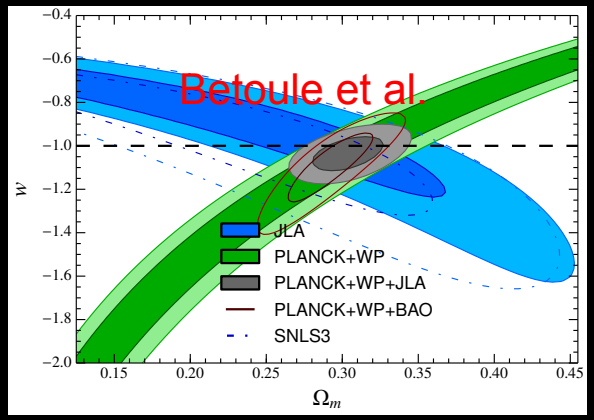
Understanding the UHECR composition is a key parameter to test the coherence of our High Energy picture.

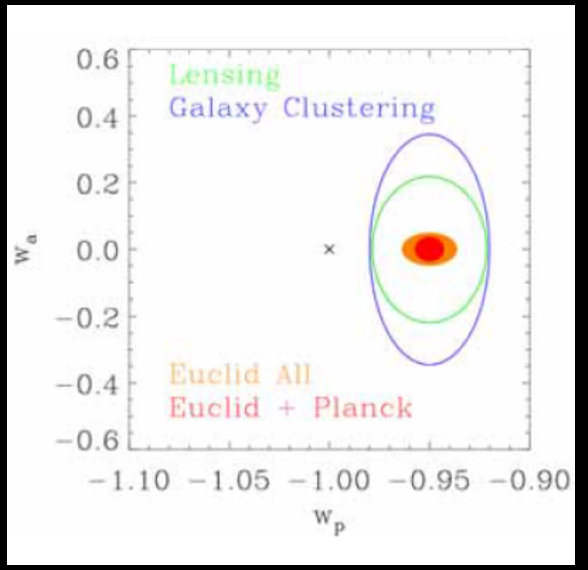
The European Astroparticle Physics Roadmap III (2020-2035)

- Dark Energy and CMB
  - *In Space: EUCLID (ESA, NASA)*
  - *On ground: participation to LSST*
- Gravitational waves
  - ET Einstein Telescope (provided detection by advGW)
  - eLISA (ESA, L3 mission 2034, *NEW !!!*)

Dark energy
From the Legacy Survey to EUCLID and LSST

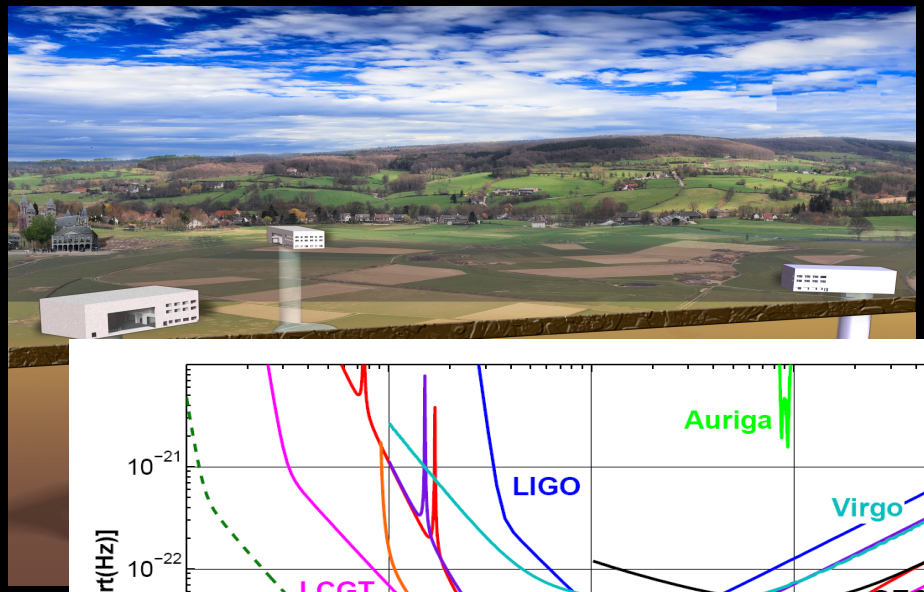
- SNLS has been a key element in the determination of dark energy parameters.
- EUCLID is an ESA M2 mission (NASA participation) a 1.2 m telescope at L2 with visible and NIR imaging, NIR slitless spectroscopy.
  - Launch 2020, 6(+1) years of operation
  - Probes: cosmic shear, BAO, galaxy cluster, CMB cross-correlations, SN1a. Legacy science.
  - Measure through redshift and lensing the sum of neutrino masses with σ=25 meV
  - Needs ground-based optical imaging for photo-z estimates
- Complementary in systematics to LSST: superior spectroscopy (LSST) vs absence of atmospheric distortion (EUCLID)
- APPEC recommended since 2011 the participation to both LSST and EUCLID. Biggest challenge the data exchange in accordance with priority rights

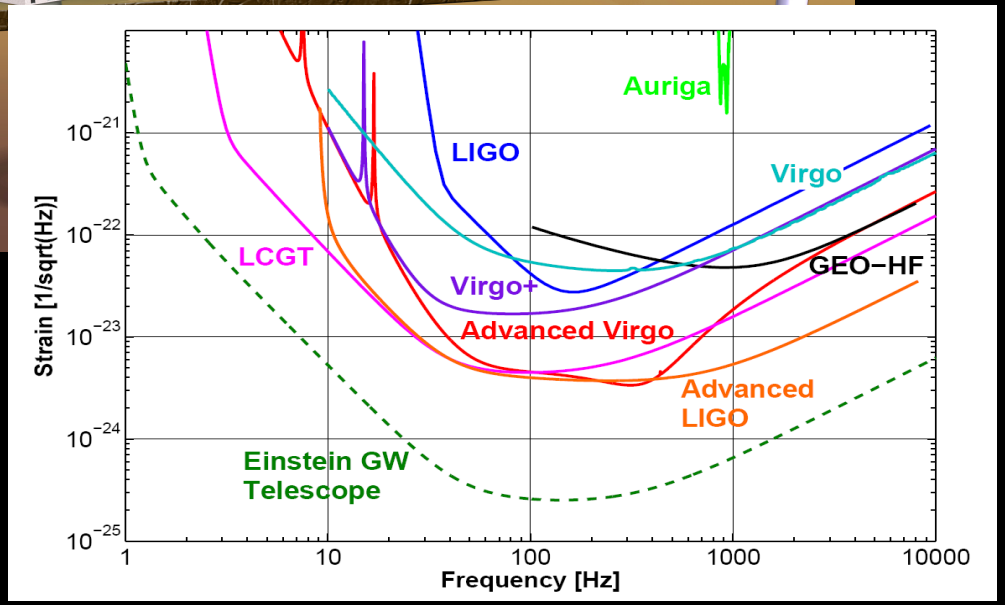


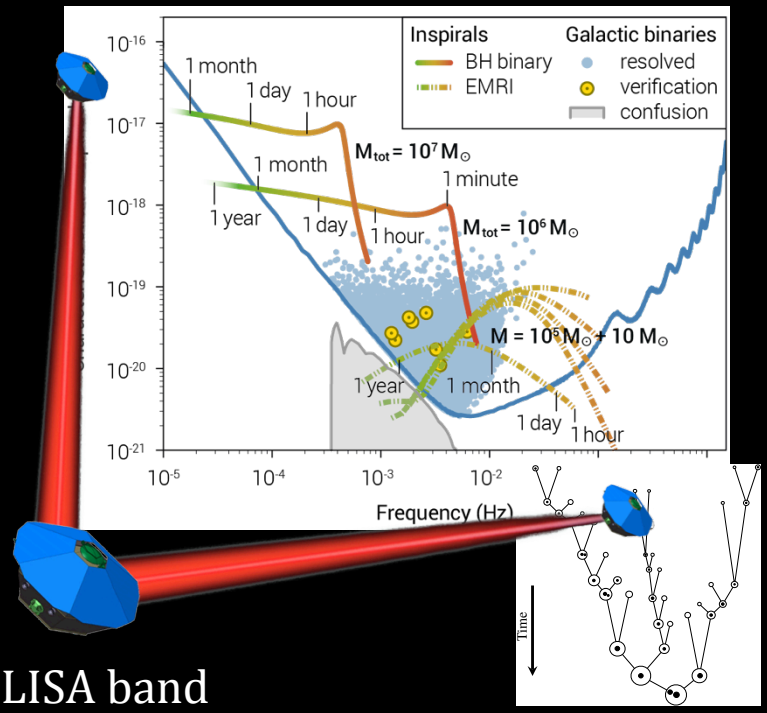


GWA further in the future

Einstein Telescope (ET) and eLISA







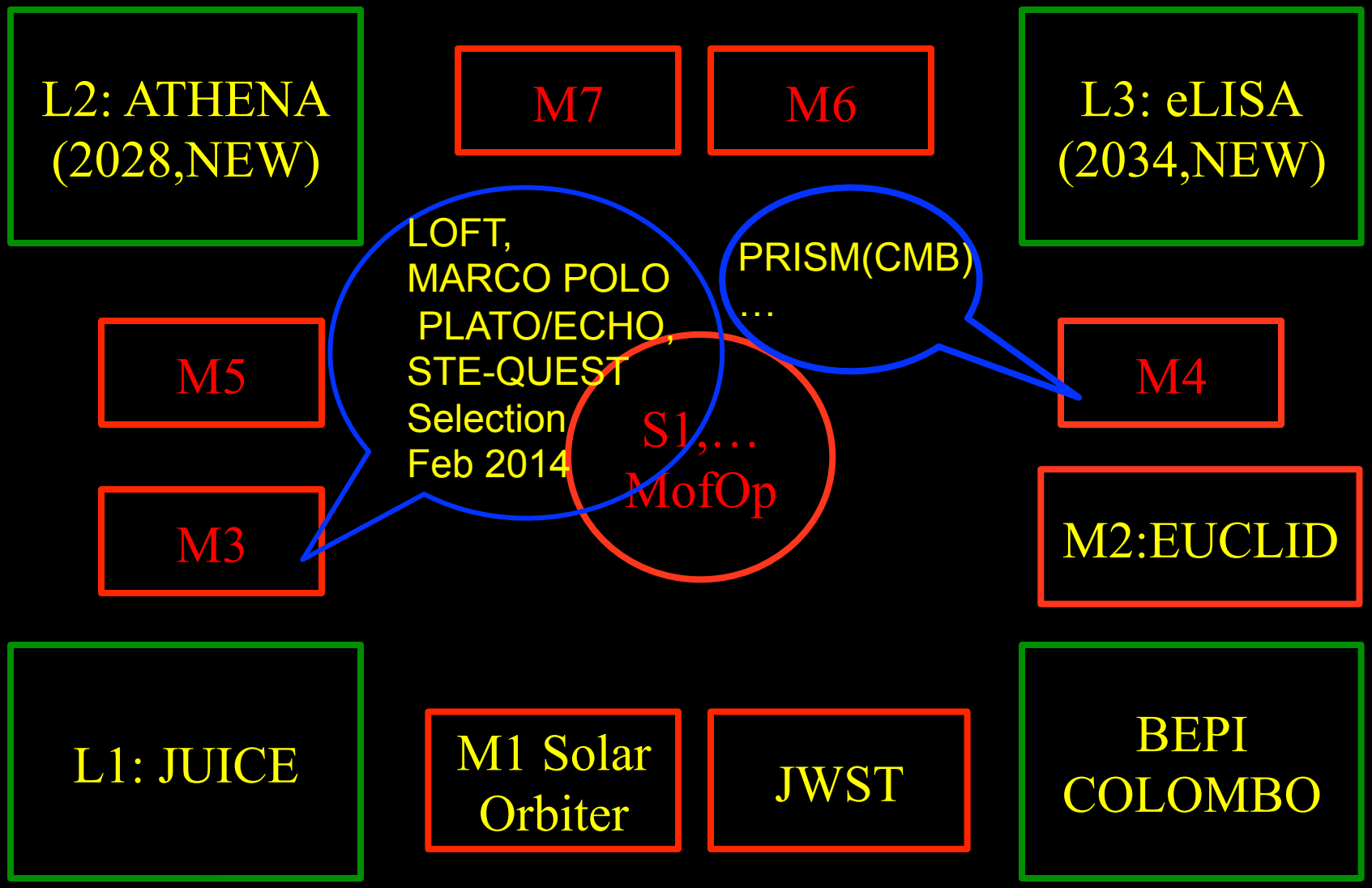
eLISA band

- 0.1-100 mHz ⟹ 1-1000 TeV (LHC)
- Phase transitions,
- Topological defects…
- Higgs self-couplings and potential
- Supersymmetry
- Extra dimensions
- Strings

✓ ET: If detection by 2018 move to third generation (ca 2020) . ASPERA/ApPEC funding for R&D

Cosmic Vision 2015-2035

Adapted from presentation of A. Giménez at ESSC, 15 May 2013



Conclusions

- *Exciting times: new data bring new physics on focus, the coronation of standard model(s) usually precedes the opportunity to "overthrow them.*

- *Astroparticle Physics enters into a period of globalisation and focusing to a few large projects*

- *The European process of prioritisation in parallel with the US one , many common choices*

- *Good coordination in some areas*
  - *Grav. Waves, Dark Energy, Auger-EUSO, CTA, Global Neutrino Network*
- *More encouragement is needed in some others:*
  - *Dark matter*
  - *Neutrinos (mass and oscillations)*

- *The new European framework program Hortizon 2020 offers opportunities of funding for global coordination actions, we intend to exploit them to increase coordination with US but also other regions of the world.*

Spare slides

APPEC statement for Neutrino (input to European Strategy process, January 2013)

Support for:

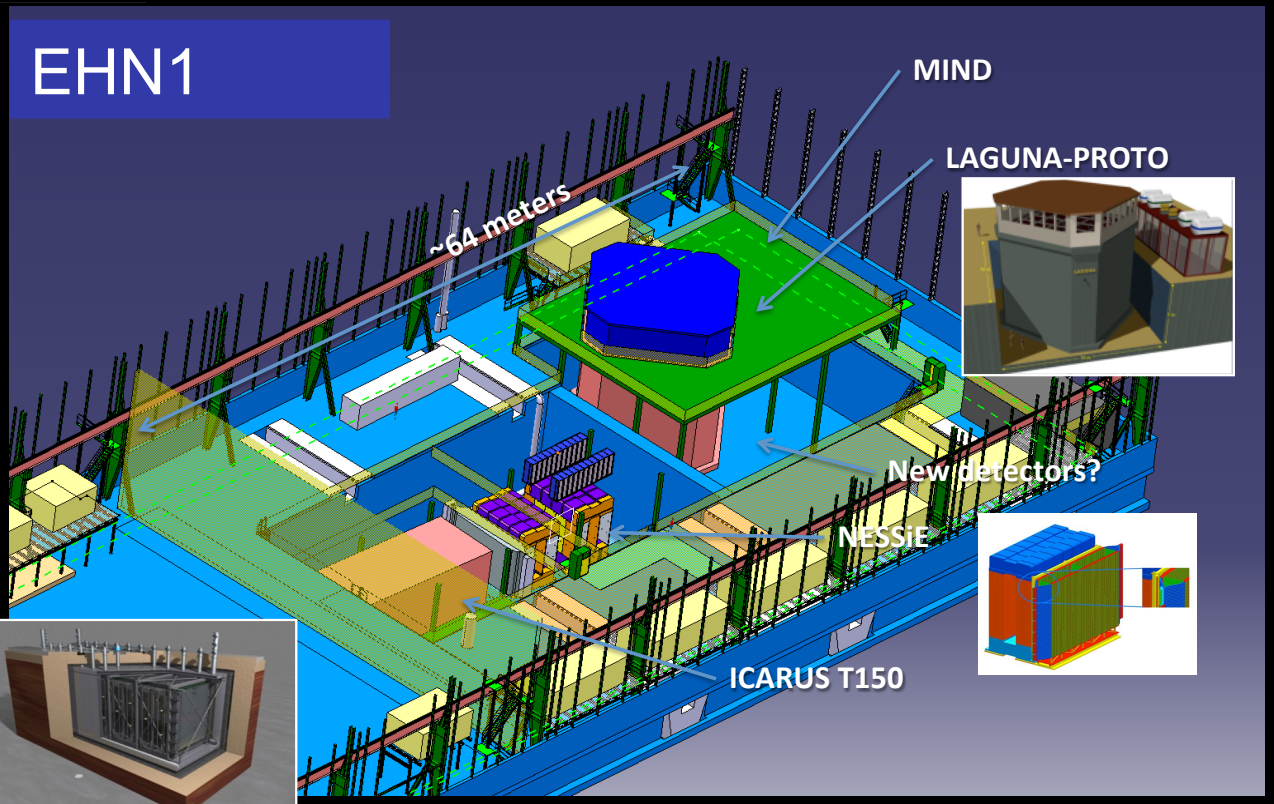
1. A vigorous R&D program and prototyping on the liquid argon detector technique and beam design studies in anticipation of a critical decision in 2015-16 for a strong European participation in a long baseline experiment outside Europe or an experiment in Europe. The detector should have an adequate mass and be deployed deep enough underground to have any relevance for Astroparticle Physics.

2. The design and cost studies of very large neutrino detectors optimised for proton decay and astroparticle physics using the techniques of liquid scintillator or water in view of the construction of at least one of these detectors somewhere in the world. In the same context we support studies aiming at the clarification of the possibility to determine the mass hierarchy with underwater/ice detectors and atmospheric neutrinos.

3. The current efforts for the determination of the neutrino's fundamental nature (Majorana or Dirac) and the absolute scale of the neutrino masses.

4. The current program testing the sterile neutrino hypothesis

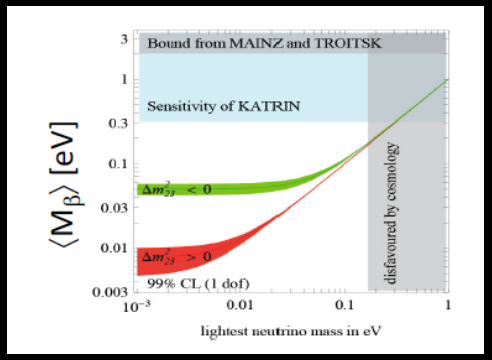
A neutrino program for R&D and prototyping back to CERN



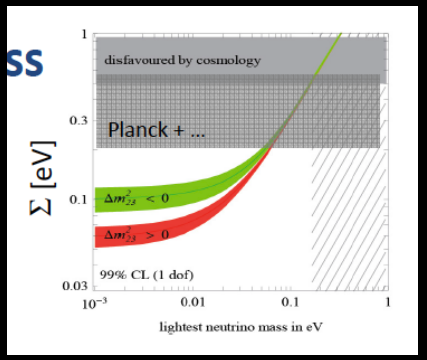
- WA105 (LAGUNA-LBNO), 2-phase LAr prototype
  - Joint task force with LBNE on physics program
- WA104 (ICARUS)
  - Refurbish ICARUS and R&D for a sterile neutrino experiment
  - Discussions for common R&D with LBNE
- A neutrino (test)beam study in NA

From the CERN strategy document : *CERN should develop a neutrino programme to pave the way for a substantial European role in future long-baseline experiments. Europe should explore the possibility of major participation in leading long-baseline neutrino projects i n the US and Japan.*

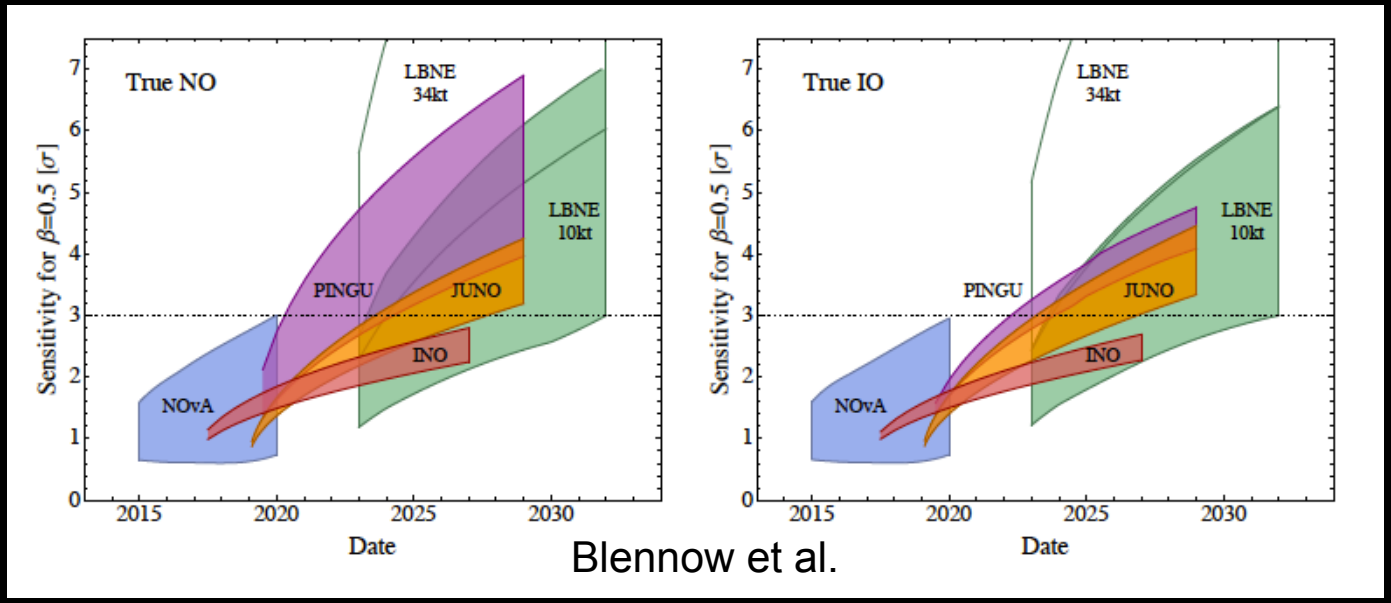
Also ESS study for an intense low energy beam, Protvino beam to somewhere in Europe.



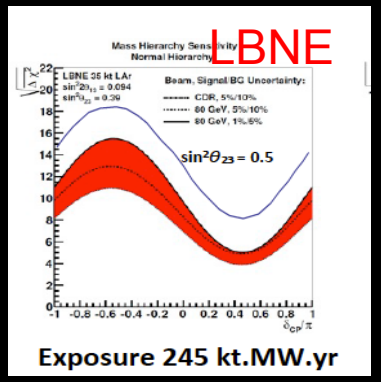
A personal comment: The importance of the neutrino mass hierarchy



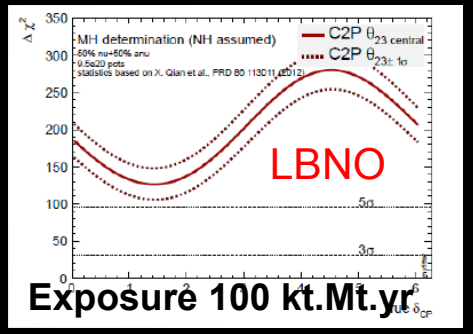
There is currently the tendency to treat the determination of the neutrino mass hierarchy as a temporary but necessary stop in the way to the determination of the CP violation parameter. Nevertheless and in view of the statistical treatment issues appearing recently, we should remember that this is the parameter that will be directly confronted to the cosmological measurements coming ca 2020, and will be a determining factor to the double/single beta mass program.



Blennow et al.



Exposure 245 kt.MW.yr



Exposure 100 kt.Mt.yr